US009145749B1

(12) **United States Patent**
Clark, II

(10) **Patent No.: US 9,145,749 B1**
(45) **Date of Patent: *Sep. 29, 2015**

(54) **METHOD OF CUTTING TARGET MEMBERS USING A CUTTING SAW DEVICE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 64 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/920,447**

(22) Filed: **Jun. 18, 2013**

Related U.S. Application Data

(63) Continuation of application No. 13/367,492, filed on Feb. 7, 2012, now Pat. No. 8,465,227, which is a continuation of application No. 13/084,726, filed on Apr. 12, 2011, now Pat. No. 8,109,693, which is a continuation of application No. 12/142,893, filed on Jun. 20, 2008, now Pat. No. 7,922,424.

(51) **Int. Cl.**

E03F 3/06	(2006.01)
E21B 29/00	(2006.01)
B26D 1/547	(2006.01)

(52) **U.S. Cl.**
CPC ***E21B 29/007*** (2013.01); ***B26D 1/547*** (2013.01)

(58) **Field of Classification Search**
USPC 405/85, 156, 190, 191; 114/4.1; 125/16.02, 21; 83/200.1, 307.1, 307.3, 83/651.1; 166/361
See application file for complete search history.

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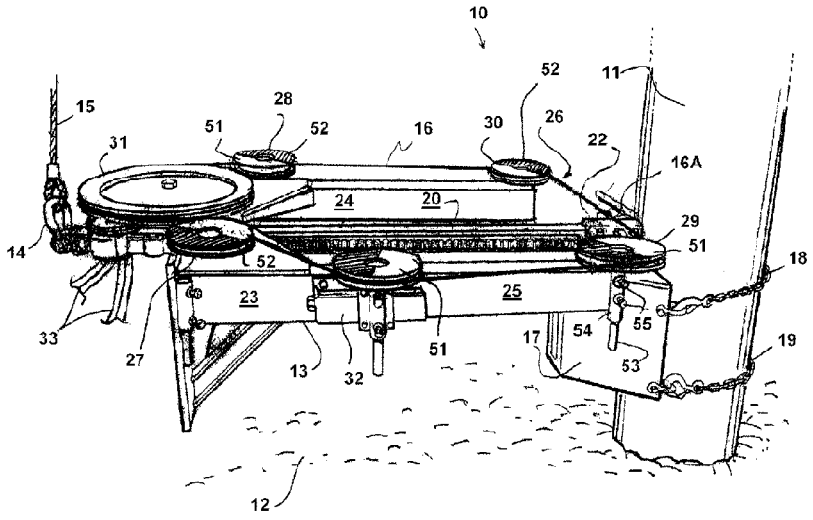
(57) **ABSTRACT**

A diamond wire saw and method provides a frame that includes a clamp that attaches to a target (e.g. piling, beam, tubular), an elongated toothed rack extending away from the mount and target, and a moving portion that carries the diamond wire and motor drives that advance the moving portion toward the target and along the toothed rack while driving the wire around roller guides.

19 Claims, 14 Drawing Sheets



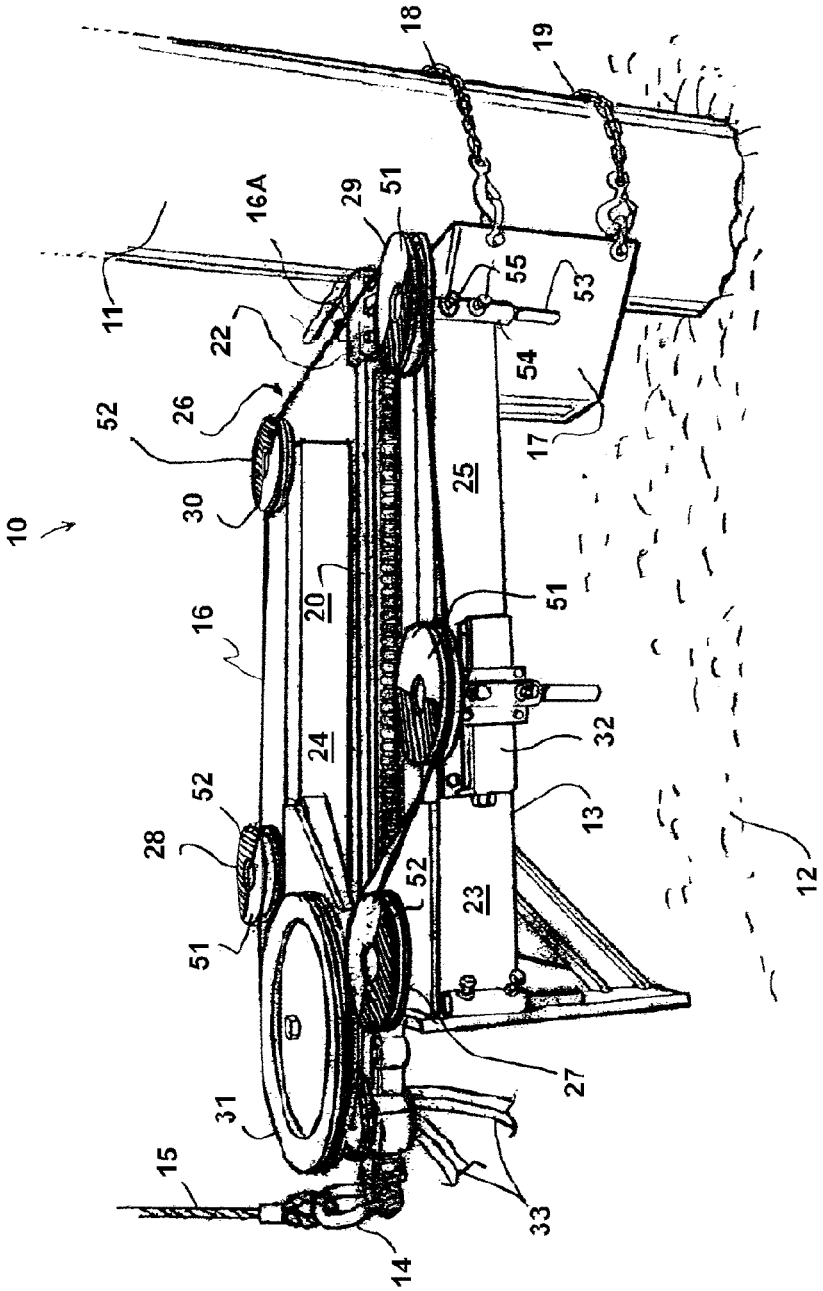

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FIG. 1

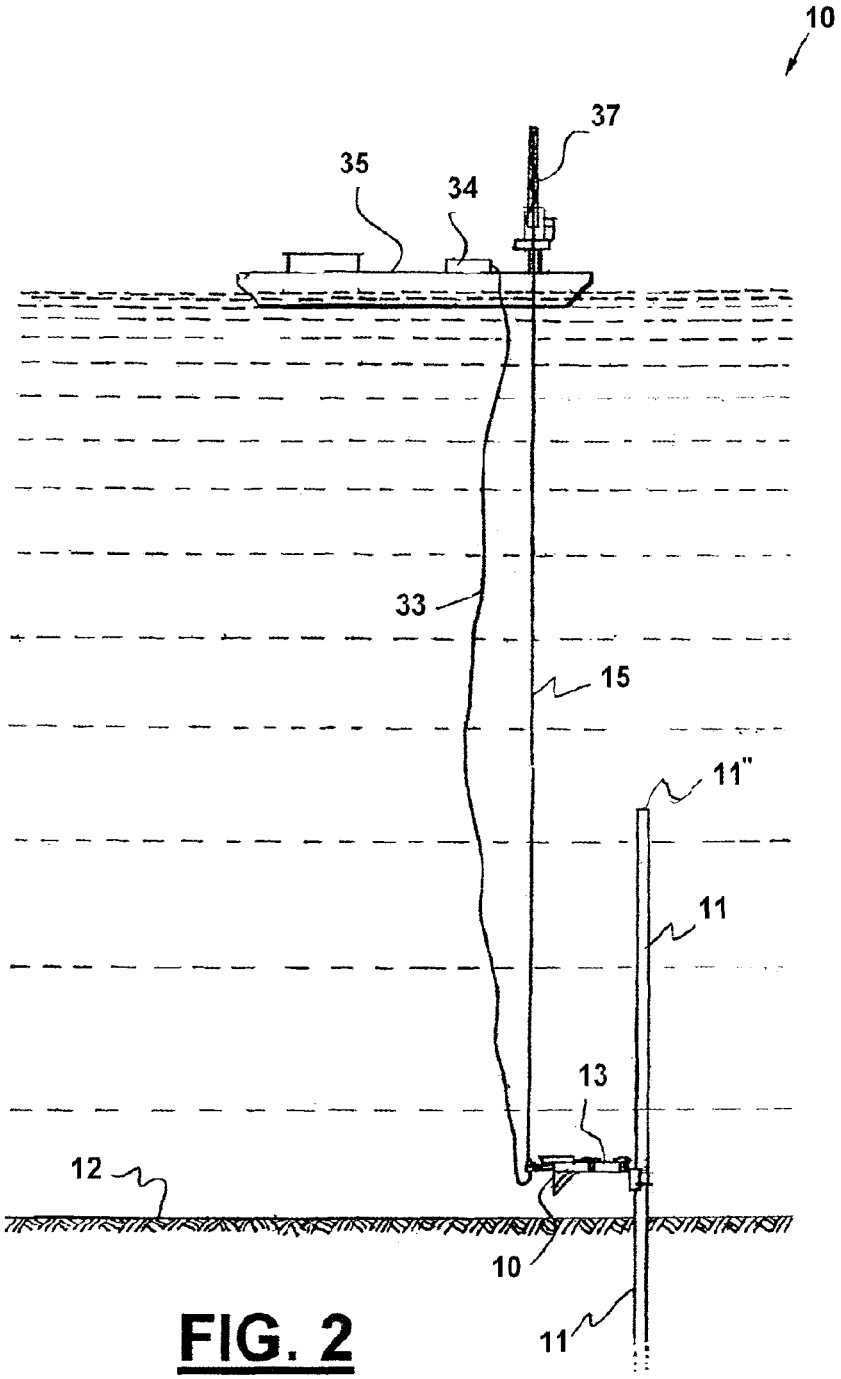

FIG. 2

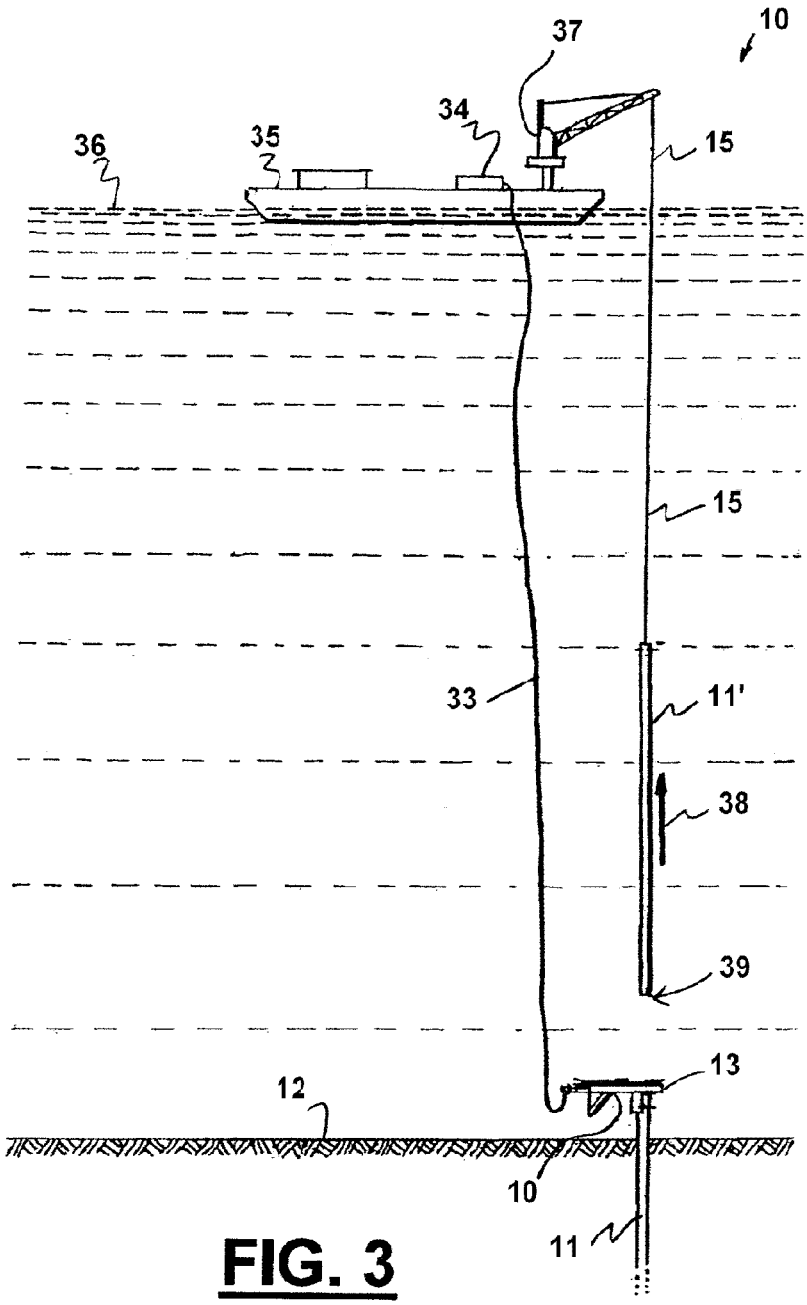

FIG. 3

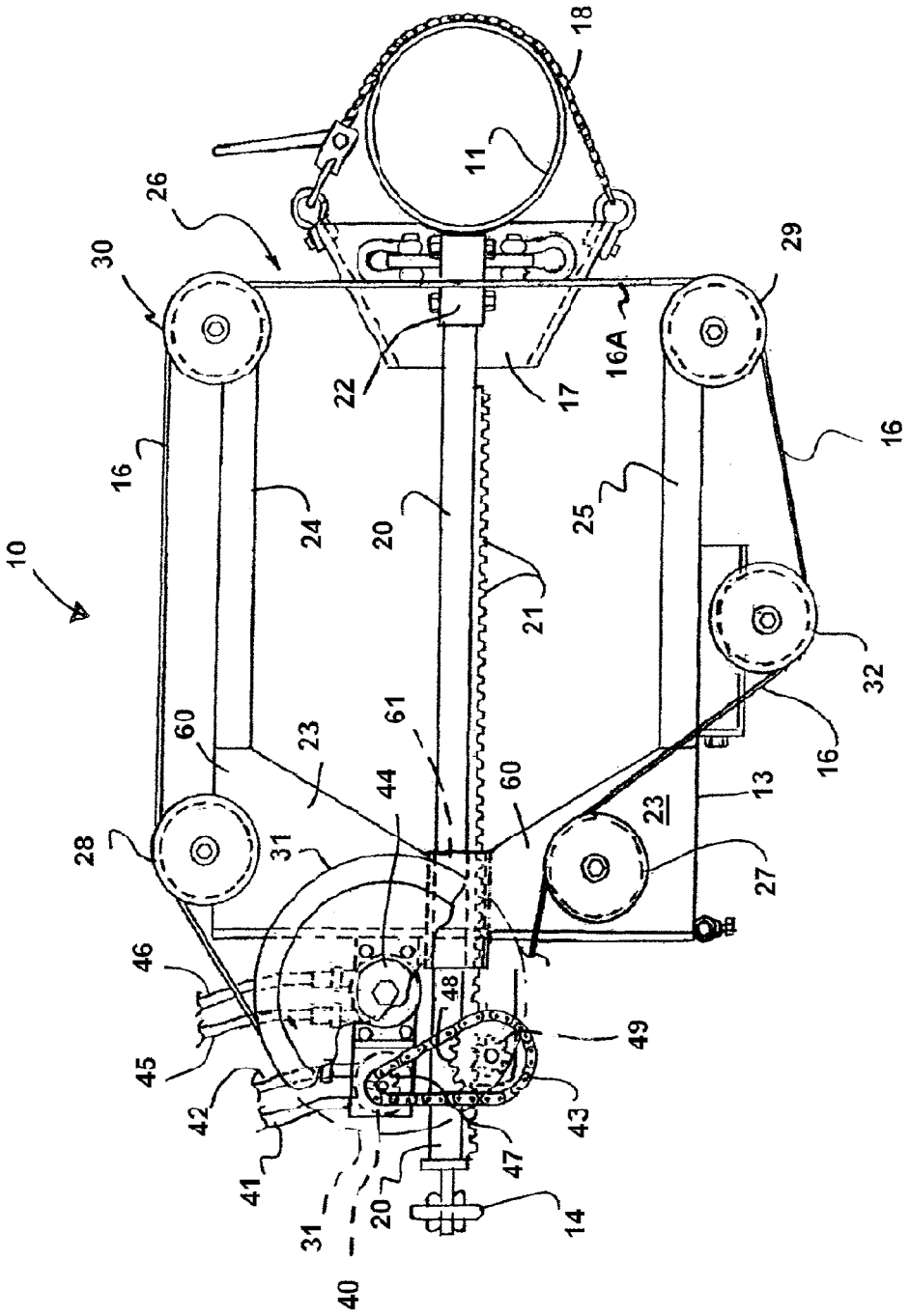
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FIG. 4

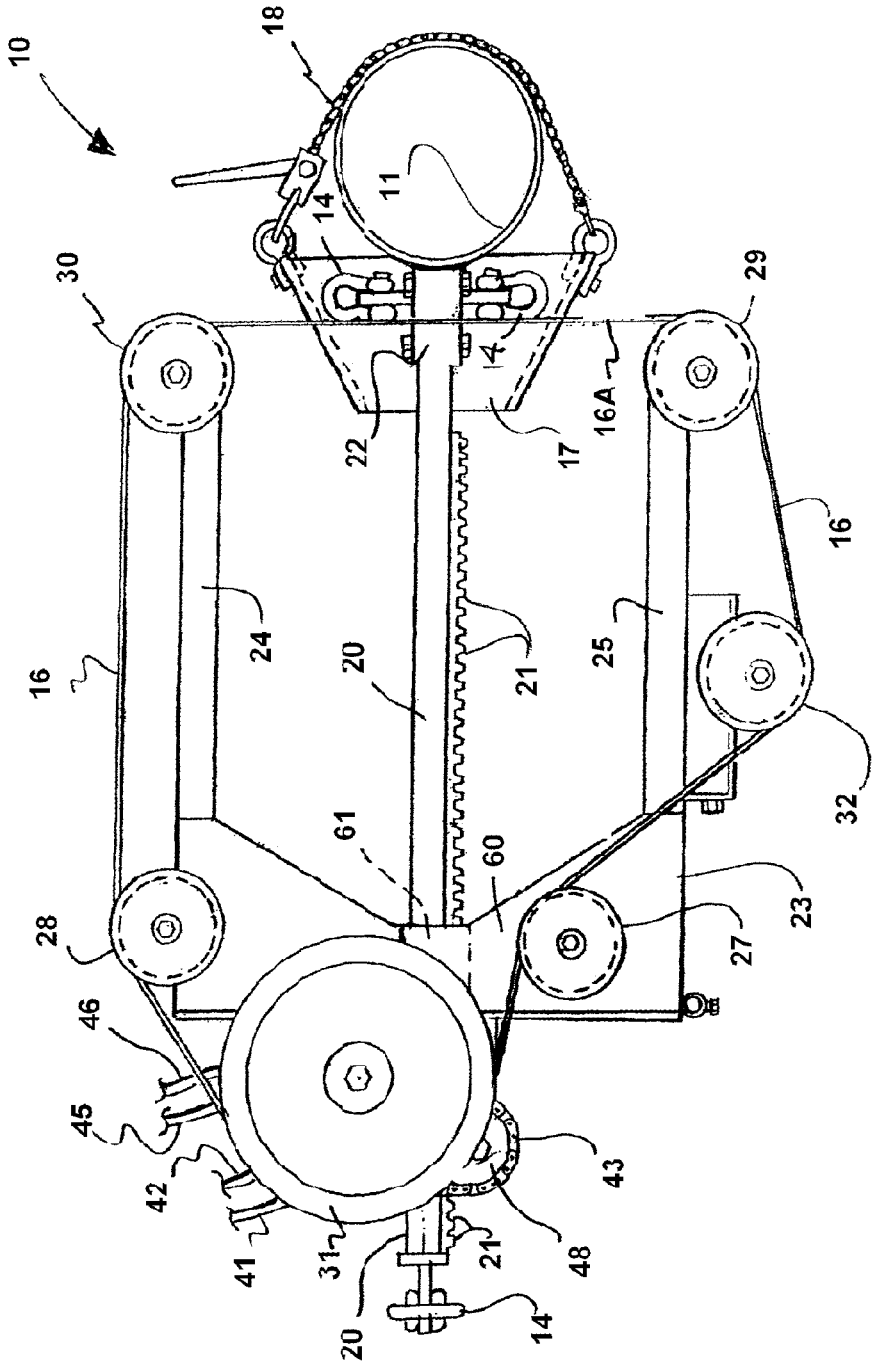
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FIG. 5

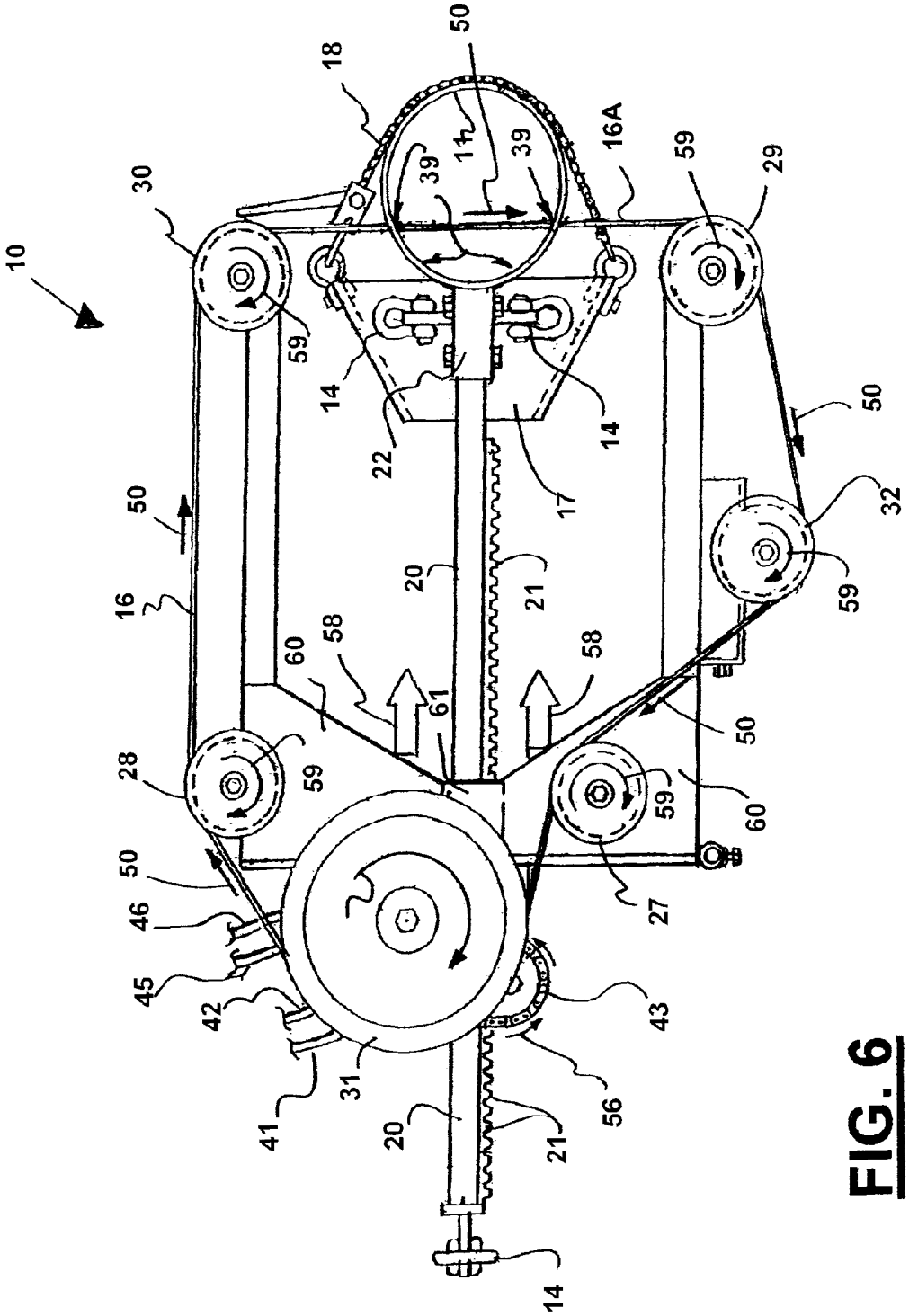
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FIG. 6

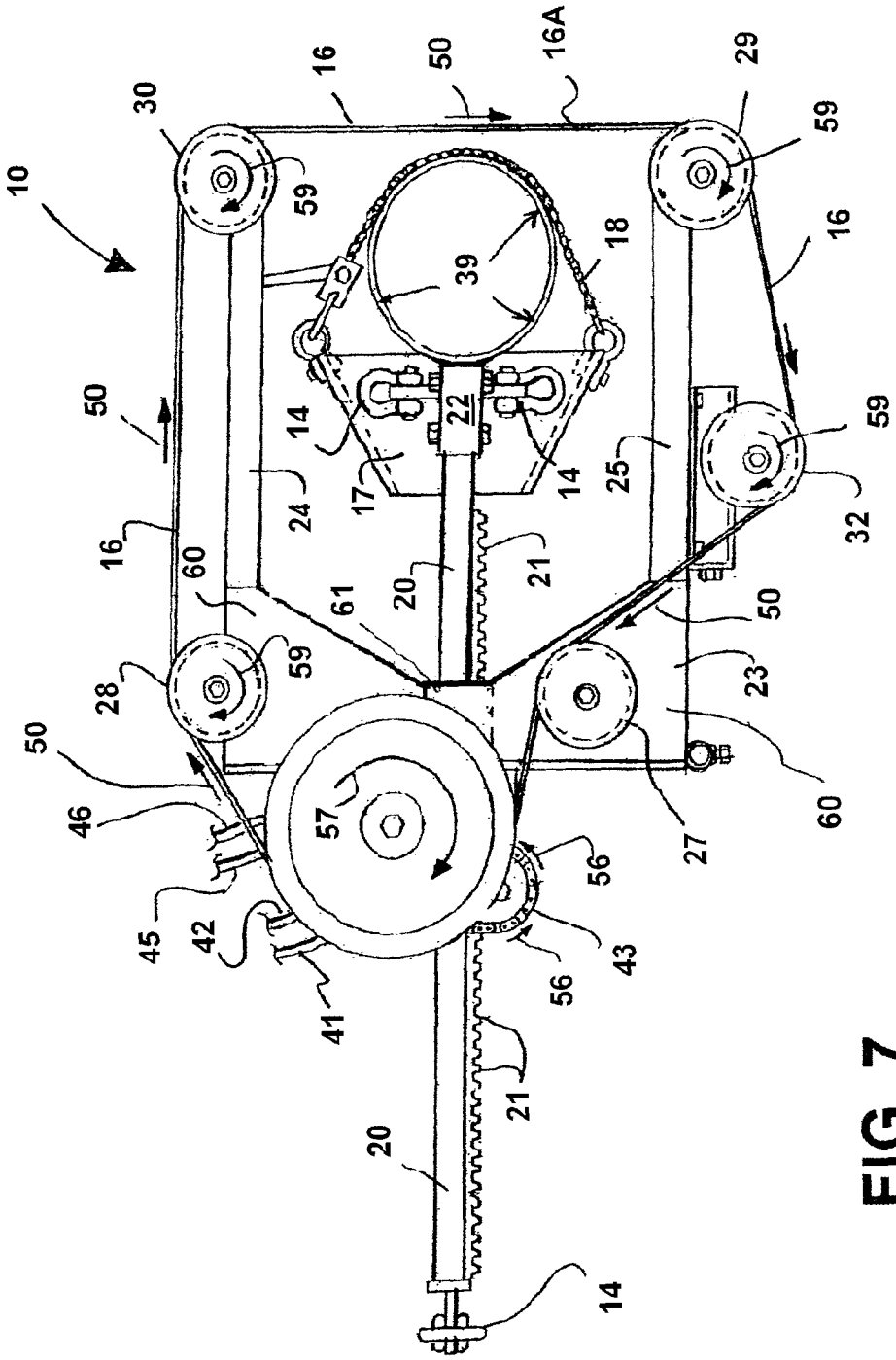
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FIG. 7

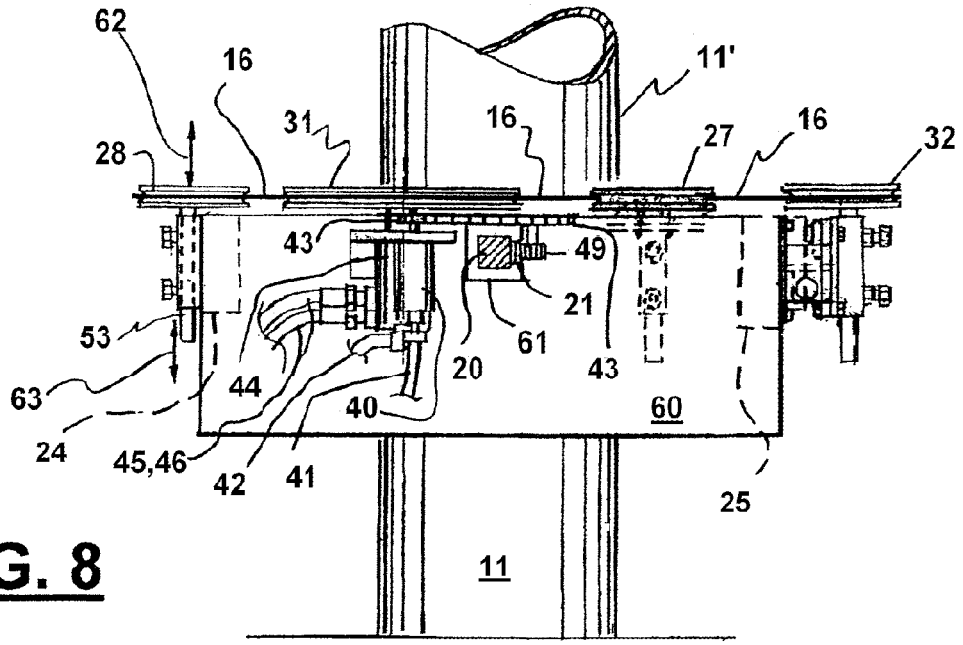
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FIG. 8

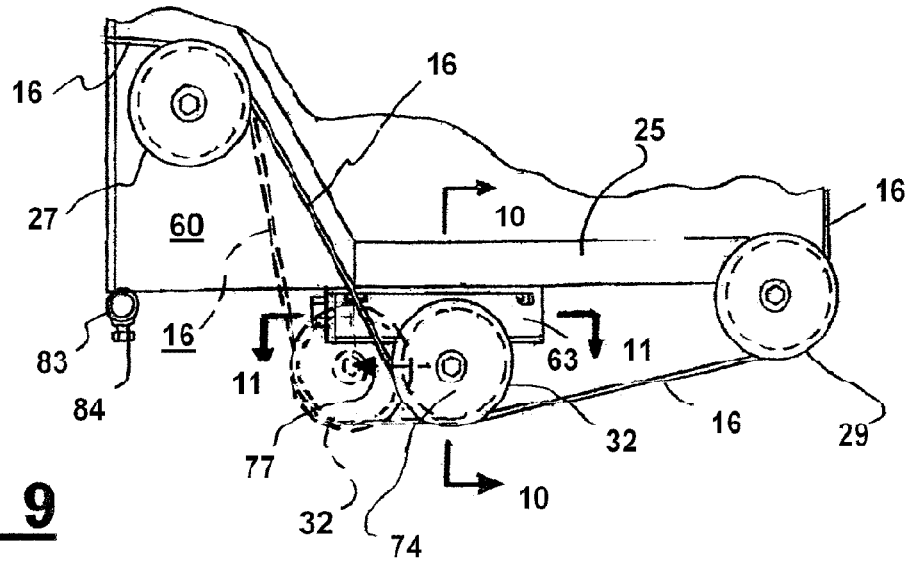
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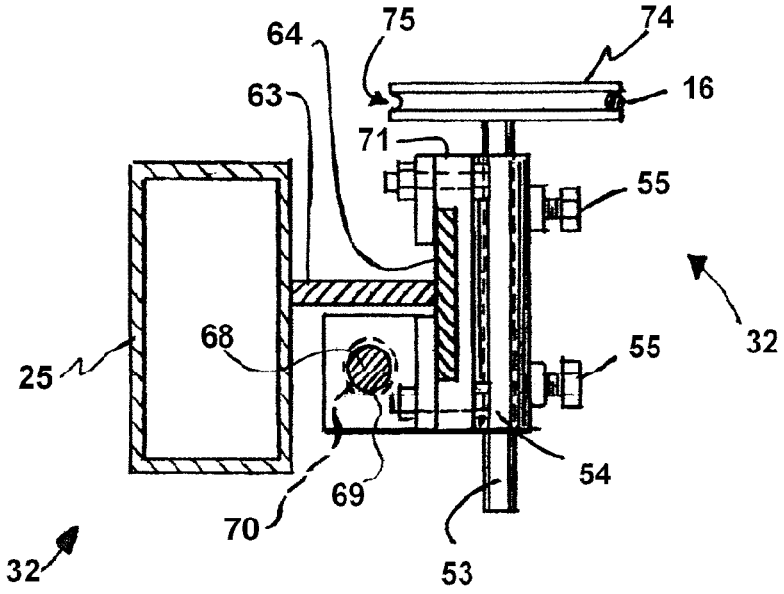
FIG. 9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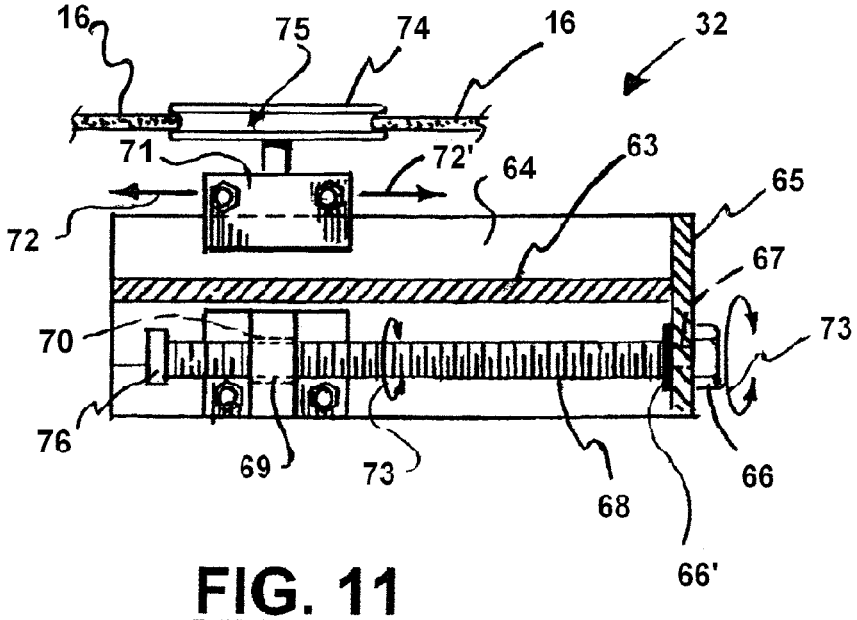
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FIG. 11

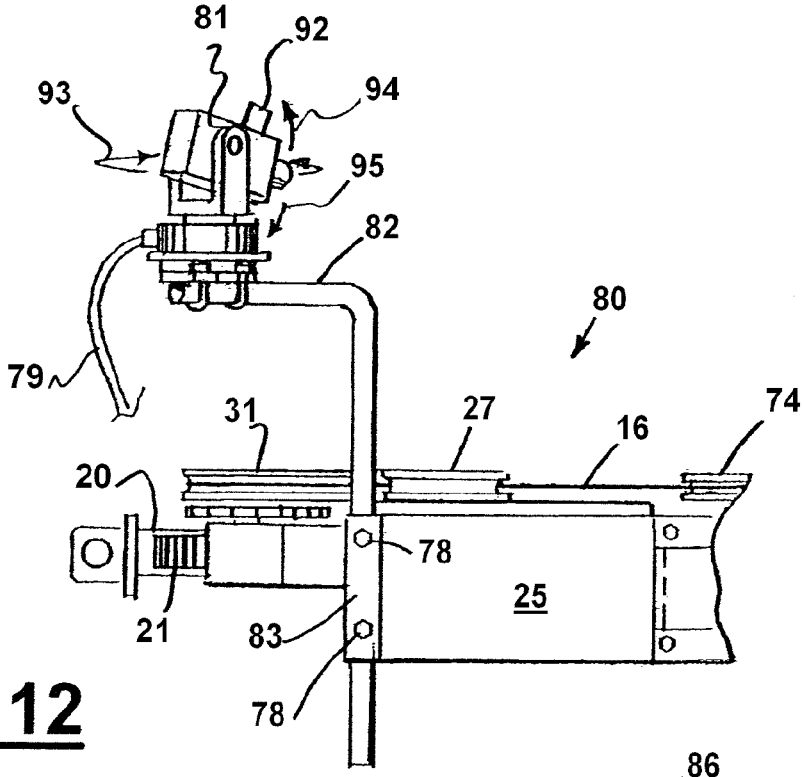
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FIG. 12

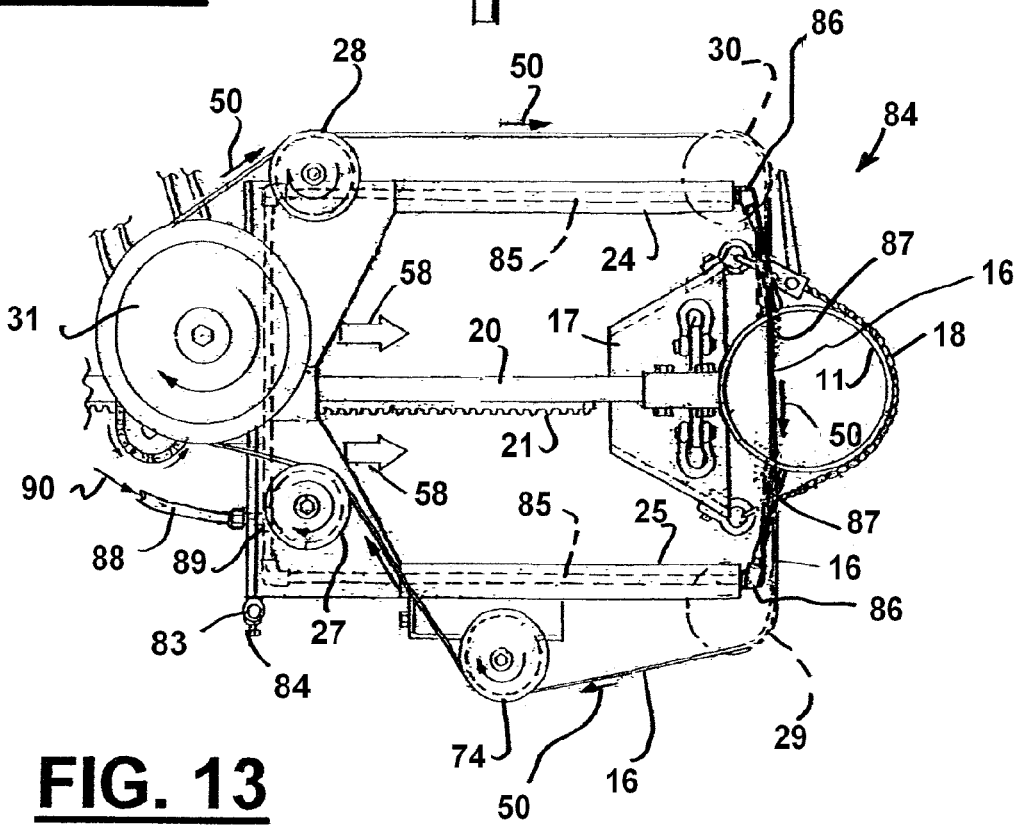
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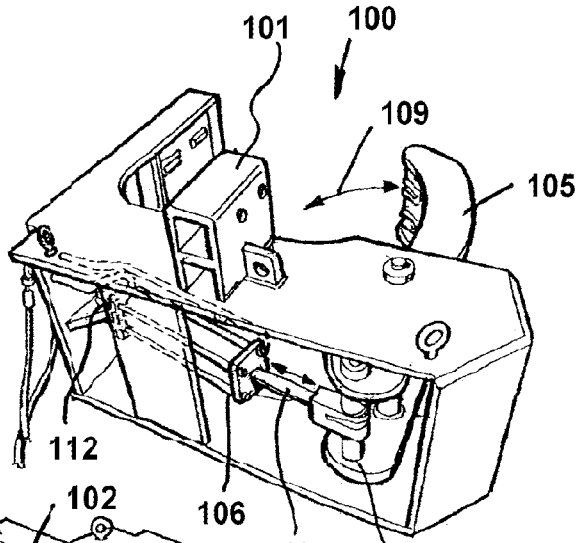
FIG. 13



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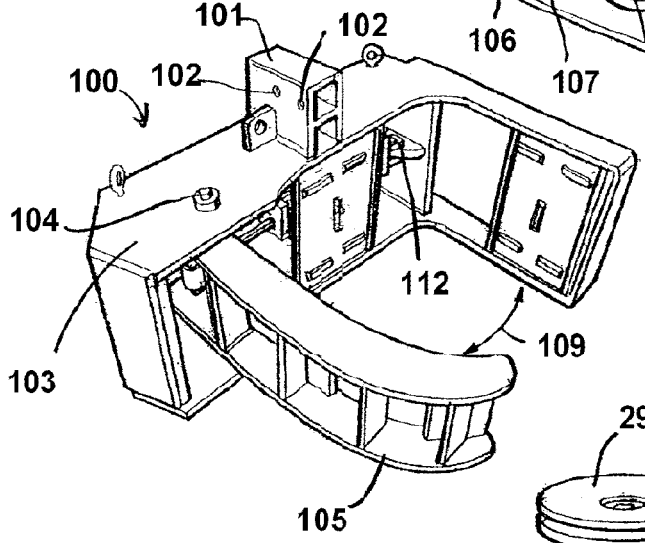

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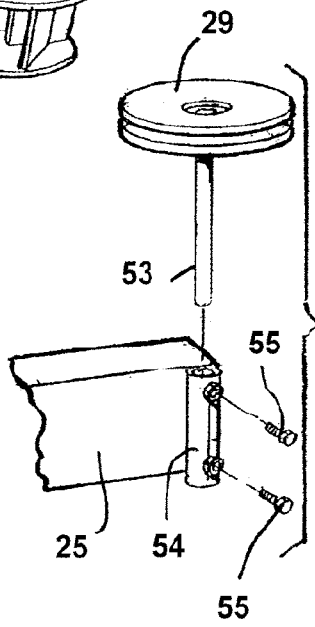

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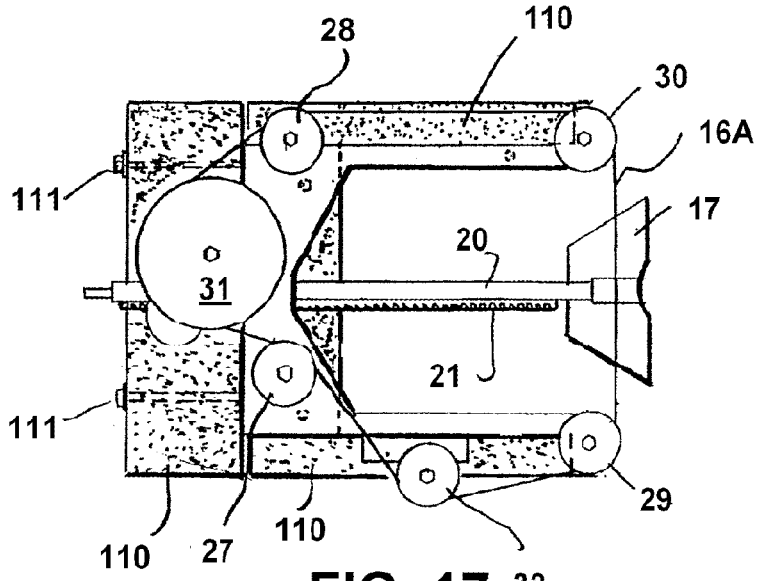
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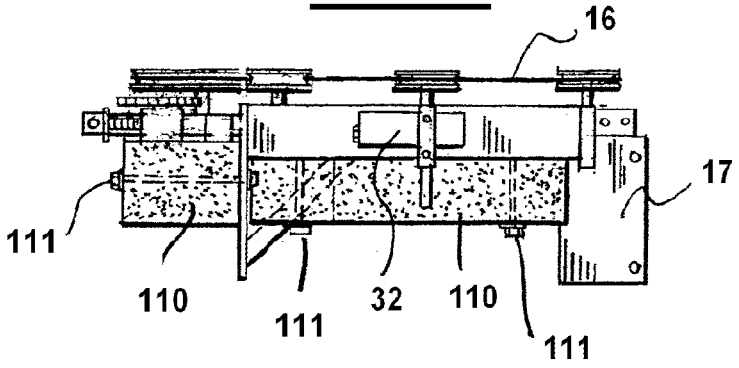
FIG. 17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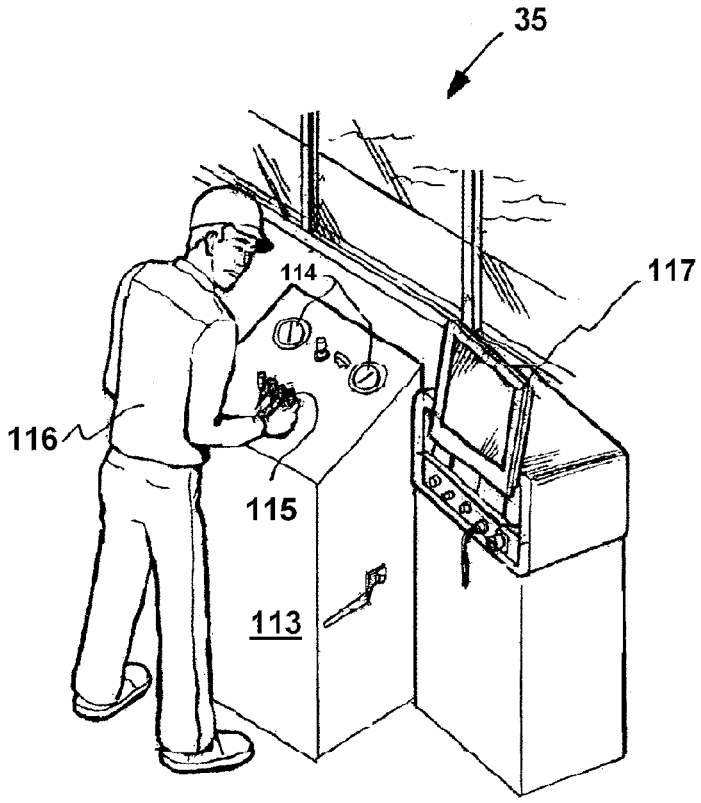
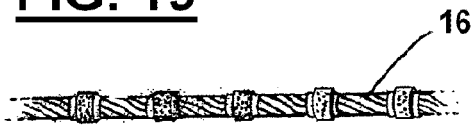


FIG. 19



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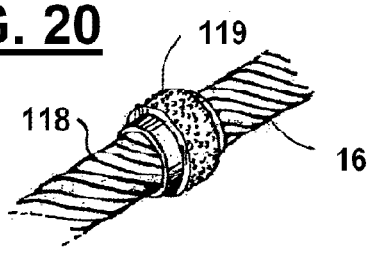

FIG. 21

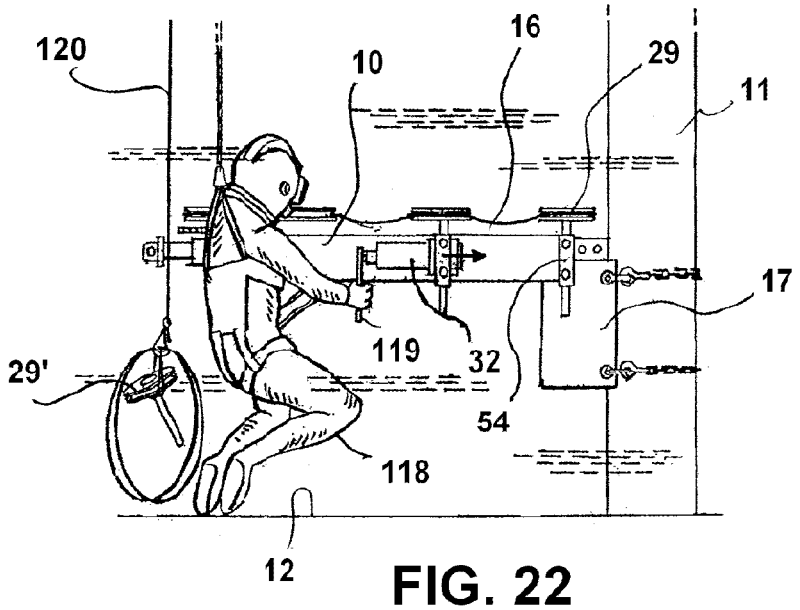

FIG. 22

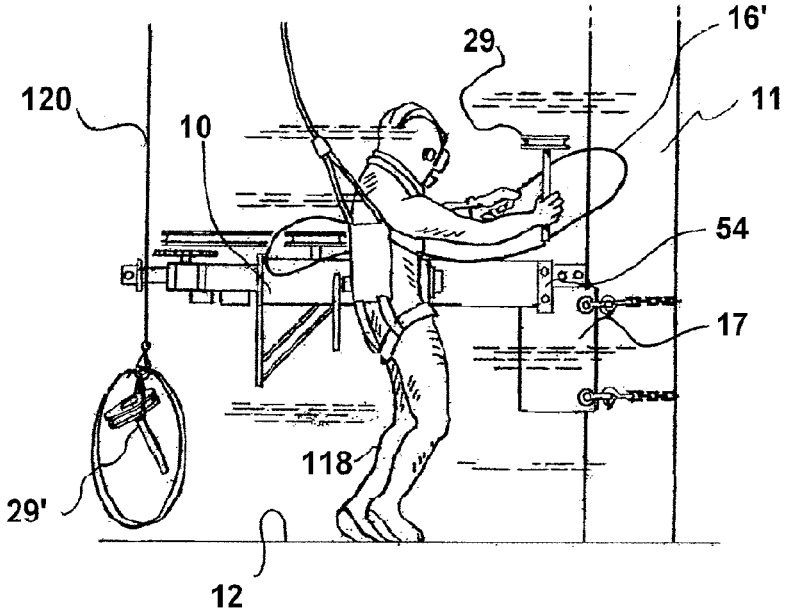

FIG. 23

METHOD OF CUTTING TARGET MEMBERS USING A CUTTING SAW DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation of U.S. patent application Ser. No. 13/367,492, filed Feb. 7, 2012 (issuing as U.S. Pat. No. 8,465,227 on Jun. 18, 2013), which was a continuation of U.S. patent application Ser. No. 13/084,726, filed Apr. 12, 2011 (issued as U.S. Pat. No. 8,109,693 on Feb. 7, 2012), which was a continuation of U.S. patent application Ser. No. 12/142,893, filed Jun. 20, 2008, (issued as U.S. Pat. No. 7,922,424 on Apr. 12, 2011), which applications are incorporated herein by reference. Priority of these applications is hereby claimed.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable

REFERENCE TO A "MICROFICHE APPENDIX"

Not applicable

BACKGROUND

The present invention relates to the removal of targets (e.g. underwater tubular members) as a part of oil well intervention and decommissioning. More particularly, the present invention relates to a method and apparatus of cutting of targets above and below the water line such as tubular members associated with oil and gas well drilling platforms and production platforms. Even more particularly, the present invention relates to an underwater cutting method that provides cold-cutting of targets, tubular members, or "tubulars" using a specially configured diamond wire saw arrangement.

The following patents are directed to diamond wire saws and continuous wire saws as well as methods of cutting structures underwater.

SUMMARY

In one embodiment is provided an underwater cutting apparatus and method of compact size, lightweight and simple design.

In one embodiment is provided a cold-cutting saw device that employs two remotely controlled motors, preferably hydraulic motors mounted to a frame such as a lightweight aluminum frame.

In one embodiment one of the hydraulic motors propels or circulates a continuous loop of diamond wire (for example, 5/8 inches outer diameter) that is wound about a series of alignment wheels or sheaves. In one embodiment the cutting diamond wire can travel at a rate of between about 20 and 25 feet per second as an example.

In one embodiment is provided a second motor drive moves a pinion gear of a rack and pinion mechanism. This rack and pinion mechanism moves a part of the frame along a feed shaft (for example, composite or steel). The movement of part of the frame pushes or pulls the circulating diamond wire into and through the target material or tubular as it is cut.

In one embodiment the feed shaft can contain the teeth of the rack, and the feed shaft can support the weight of the saw frame. The feed shaft can also stabilize the cutting wire, maintaining the cutting wire in a constant plane that is generally normal to a mounting clamp and the material being cut.

In one embodiment a mounting clamp can be used to secure the entire saw assembly to the target or tubular or other material being cut utilizing a chain and binder or hydraulic clamping system.

In one embodiment the saw device can be used underwater, above water, and/or in dangerous to human environments, such as in nuclear reactors.

In one embodiment the saw device can be used to cut various combinations of solid and tubular dissimilar steels, synthetic composite materials, or dissimilar aggregates (concrete).

In one embodiment the saw device can be used to cut different size materials ranging from about two inches to about ninety-six inches in diameter as the target.

One embodiment includes a single, centralized feed shaft controllably slidable over a rack and pinion feeds mechanism which controls the feed and/or retraction amount/rate of the cutting diamond wire.

One embodiment includes a centralized feed shaft which has two longitudinal arms each longitudinal arm having a feed shaft controllably slidable over a rack and pinion feeds mechanism which controls the feed and/or retraction amount/rate of the cutting diamond wire. In this embodiment two feed motors and gears can be used to control feed and/or retraction of the cutting wire.

One embodiment includes a rectangular or square feed shaft for stabilizing the saw and maintaining the cutting wire perpendicular to a positioning clamp during cutting movements of the cutting wire.

In one embodiment the cutting saw frame is generally U-shaped allowing both a pushing type cut for the cutting wire and a pulling type cut for the cutting wire.

In one embodiment a plurality of alignment wheels or sheaves are arranged symmetrically on the saw frame to provide uniform tension to the cutting wire during operation.

In one embodiment one or more of the alignment wheels or sheaves have motion indicating indicia depicting movement of the cutting wire. In one embodiment one or more of the alignment wheels or sheaves have a rotating surface which includes a plurality of indicia markings. In one embodiment one or more of the alignment wheels or sheaves include a surface which is of two colors. In one embodiment one or more of the alignment wheels or sheaves are about 50 percent one color and 50 percent another color. The cutting indicia on the one or more alignment wheels or sheaves as they spin provides a visual indicator of when the cutting wire is in motion. In one embodiment the speed of rotation of the indicia on the alignment wheels or sheaves provides a visual indicator of the relative speed of the cutting wire.

In one embodiment the saw device can include a wire tensioning system which has an axial feed for the tension system. In one embodiment the axial feed tensioning system can be manually operated.

In one embodiment the cutting saw can include a cutting coolant system for providing lubricating and/or cooling liquids on the wire during cutting operations. In one embodiment the cooling system can include one or more spray nozzles.

In one embodiment the saw device can include a platform design for saw sizes to cut materials from 2" OD and greater. In one embodiment the saw device can be sized from a 26" cutting area to a 100" cutting area. In one embodiment a single man portable version of the saw device can be provided having a relatively small opening (such as 14 inches) for single man operations (e.g., where one man can easily lift and position the cutting while above water).

In one embodiment the saw device can be mounted on the target and clamped in place using a remote operated vehicle ("ROV") and the saw device being controlled remotely from the surface, or the saw can be operated independently utilizing the hydraulic system integrated into many ROV systems with its full control under the command of the ROV operator. In this embodiment the cutting saw can include a remote operated clamping system (such as a hydraulic clamp). The ROV will have the cutting saw with the remote operated clamping system attached to the ROV, and the ROV will position the cutting saw at the place of cut on the target, and the clamping system will be activated remotely causing the saw to attach to the target, and the cutting saw will be remotely activated causing the cutting wire to spin. The cutting wire will be remotely moved forward by the topside operator and the cut made similar to operations under other embodiments. However, the ROV will remain attached to the cutting saw during and after the cut is made. After the cut is made the ROV can bring the cutting saw to the surface or can bring the cutting saw to the next target to be cut.

In one embodiment the saw device can include a bulkhead for the placement of "hot stab" hydraulic connections for use with ROV systems.

In one embodiment the saw device can include a flotation system. In one embodiment this floatation system can be one or more modules of syntactic foam. In one embodiment the floatation system provides about neutral buoyancy to the saw device. In one embodiment the floatation modules can be attached to the saw and/or mounted inside void spaces of the saw. In one embodiment buoyancy modules are used in combination with ROV operations. In one embodiment buoyancy modules are used to assist diver handling, positioning, and placement of the saw device.

In one embodiment lifting sling attach points allow the use of quick release shackles to speed diver and/or ROV manipulation during saw device mounting to the target material.

In one embodiment the cutting saw apparatus can include an emergency shutoff system. In one embodiment a remotely operated emergency shutoff system can be connected to the cutting saw. In one embodiment the remote shutoff can be remote from an operator's shutoff for the cutting saw. In one embodiment this remote shutoff can be under the control of a Dive Supervisor or Customer Representative.

In one embodiment the saw device can be mounted to the target piece either manually such as with a manual clamp (e.g., a chain and come-along). In one embodiment the saw device can be mounted to the target piece using a hydraulic clamping system.

In one embodiment the saw device can include a mounting bracket for one or more underwater lights along with one or more cameras for visual monitoring at the surface. In one embodiment cutting operations can be visually recorded on the surface using a video monitoring system such as a video camera. In one embodiment a fiber optic cable can be used to transmit the video signal from the camera to the surface.

In one embodiment the operator of the saw device can be above water and the saw device be below water. In one embodiment the operator can use the resistance on the cutting wire to determine when to advance the cutting wire of the saw device. In one embodiment the resistance on the cutting wire can be relatively determined based on the back pressure (e.g., hydraulic back pressure) to the driving motor for the cutting wire. In one embodiment the cutting process includes the step of advancing the cutting wire a short distance, and watching the resistance on the cutting wire increase and then over time decrease (as the cut on the target is made), and after noting the decrease in wire resistance, again advancing the cutting wire and watching the resistance on the cutting wire again increase. In one embodiment these two steps of advancing the cutting wire a short distance, and watching the resistance on the cutting wire first increase and then decrease before again advancing the cutting wire are repeated a plurality of times until the cut is made through the target.

In one embodiment the operator of the saw device can advance the cutting wire until a specified resistance is seen on the cutting wire. At this point the operator can decrease the feed rate until the resistance on the cutting wire decreases. Upon decrease of the resistance to the cutting wire the operator can again increase the feed rate of the cutting wire. This feed rate adjusting process can be repeated until the cut is completed.

In one embodiment one or more of the alignment wheels or sheaves can be replaced while the saw device is underwater, such as during the middle of a cut and without moving the saw device above water.

In one embodiment the wire can be replaced while the saw device is underwater, such as during the middle of a cut and without moving the saw device above water.

In one embodiment while underwater after a first cutting wire has broken a second cutting wire can be placed on the saw device and properly tensioning without having to first return the saw device to the surface. In one embodiment the axial feed wire tensioning system can be used to properly tension the cutting wire while the saw device remains underwater.

In one embodiment the method includes the steps of:

(a) starting a cut with a pushing (or pulling) type cut;

(b) before the cut is completed, stopping the cutting wire and at least partially removing the cutting wire from the alignment wheels or sheaves;

(c) moving the saw device into a different pulling (or pushing) type cut position but without bringing the cutting saw above;

(d) placing cutting wire on the alignment wheels or sheaves; and

(e) completing the remaining portion of the cut in the other type of cutting mode.

In one embodiment step "c" is completed without repositioning the clamp holding the cutting saw on the target.

In one embodiment step "c" is performed by moving the cutting frame to a substantially extended position. In one embodiment the cutting frame is moved to a completely extended position.

In one embodiment step "c" is performed by moving the cutting frame to a substantially retracted position. In one embodiment the cutting frame is moved to a completely retracted position.

In one embodiment the same cutting wire is used during steps "a" and "e."

In one embodiment a different cutting wire is in step "e" as that used in step "a".

In one embodiment the cutting wire used in step "a" is a loop which is broken into a wire string with two ends and during step "d" the two ends are reconnected to form a loop.

In one embodiment the cutting wire used in step "a" remains in a loop and is placed around the target being cut before step "d".

In one embodiment the tensioning mechanism is used to loosen the cutting wire in step "b."

In one embodiment the tensioning mechanism is used to tension the cutting wire in step "d."

In one embodiment the method includes the steps of:

(a) starting a cut with a pushing (or pulling) type cut;

(b) before the cut is completed, the first cutting wire breaking;

(c) removing the first cutting wire from the alignment wheels or sheaves;

(d) without bringing the cutting saw above water installing a second cutting wire on the alignment wheels or sheaves;

(e) adjusting the wire tension on the second cutting wire; and

(f) completing the remaining portion of the cut with the second cutting wire.

In one embodiment the tensioning mechanism is used to loosen the first cutting wire in step "c."

In one embodiment the tensioning mechanism is used to tension the second cutting wire in step "d."

In one embodiment the method includes the step of vertically adjusting at least one of the alignment wheels or sheaves while the cutting saw remains underwater.

In one embodiment when cutting a target (such as multiple strings of ungrouted casing) where binding of the cutting wire can occur after cutting just over one-half of the way through the target. The cutting wire can be moved to the outside of the target, and without changing the clamp position, complete the cut by pulling the diamond wire through the remaining cut zone of the target material.

In one embodiment the cold-cutting saw device of the present invention can be used in a subsea environment and top side. The cutting saw of the present invention can be remotely operated. The remote operation can be monitored via saw mounted camera or cameras. The present invention can be adapted for use with remotely operated vehicles or ROV's.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

For a further understanding of the nature, objects, and advantages of the present invention, reference should be had to the following detailed description, read in conjunction with the following drawings, wherein like reference numerals denote like elements and wherein:

FIG. **1** is a perspective view of one embodiment of the apparatus;

FIG. **2** is side elevation view showing the cutting saw of FIG. **1** attached to a target before making a cut;

FIG. **3** is another elevation view showing the cutting saw of FIG. **1** after making a cut and the target being lifted by a vessels crane;

FIG. **4** is a top view of the cutting saw of FIG. **1** attached to a cutting target where the frame is completely retracted;

FIG. **5** is a top view of the cutting saw of FIG. **1** attached to a cutting target where the frame is partially extended but before starting a cut on the cutting target;

FIG. **6** is a top view of the cutting saw of FIG. **1** attached to a cutting target where the frame is partially extended making a cut on the cutting target;

FIG. **7** is a top view of the cutting saw of FIG. **1** attached to a cutting target where the frame is fully extended and has completed the cut on the cutting target (and in the position shown in FIG. **3**);

FIG. **8** is a rear view of the cutting saw of FIG. **1**;

FIG. **9** is a fragmentary plan view of the cutting saw of FIG. **1** showing the tensioning apparatus;

FIG. **10** is a fragmentary view taken along lines **10-10** of FIG. **9**;

FIG. **11** is a fragmentary view taken along lines **11-11** of FIG. **9**;

FIG. **12** is a fragmentary elevation view of the cutting saw of FIG. **1** showing a positionally controllable video camera mounted on the cutting saw (with the option of adding a light);

FIG. **13** is a plan view of the cutting saw of FIG. **1** during cutting and illustrating the cooling system;

FIG. **14** is a fragmentary perspective view illustrating the installation of an alignment wheel or sheave and schematically indicating its installation and/or vertical adjustment;

FIG. **15** is a front perspective view of an alternate hydraulic clamping arrangement;

FIG. **16** is a rear perspective view of the hydraulic clamp of FIG. **15**;

FIG. **17** is a plan view of the cutting saw of FIG. **1** showing floatation modules installed;

FIG. **18** is a side view of the cutting saw of FIG. **17**;

FIG. **19** is a partial perspective view showing a cutting saw operator at a control panel and video monitor;

FIG. **20** is a fragmentary view of one type of diamond cutting wire;

FIG. **21** is a perspective view of the cutting wire of FIG. **20**;

FIG. **22** is a perspective view showing diver adjusting the tensioner and tension on the cutting wire; and

FIG. **23** is a perspective view showing diver replacement of cutting wire and a guide roller.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. **1-23** show the preferred embodiment of the apparatus of the present invention, designated generally by the numeral **10**. Cutting apparatus **10** can be used to cut a target **11** which can be a tubular, piling, steel beam, or other underwater structure that is to be cut. Often, such targets **11** are cut as part of oil well intervention and decommissioning activities. In a preferred embodiment, the apparatus **10** of the present invention can be used in a subsea environment for subsea cutting of target **11** at or near the seabed **12**, or below the seabed **12** after an area around the target has been excavated to provide room for the cutting saw to operate. If an area around the target has been excavated a retaining wall or cofferdam can be used to resist filling of the opened space around the target.

Cutting apparatus **10** can be employed to cut a target for above water cutting when fitted with optional cooling system (FIG. **13**). Cutting apparatus **10** employs a frame **13**. The frame **13** can be supported with rigging such as shackles **14** and lift cables **15**. In FIGS. **1** and **2**, frame **13** is attached to target **11** using mounting clamp **17**. The mounting clamp **17** can be attached to the target **11** using cable/chain attachments **18**, **19**, or a hydraulic clamp (see FIGS. **15-16**).

A feed shaft **20** extends from mounting clamp **17** as shown in FIG. **1**. The mounting clamp **17** can provide a receiver **22** that enables attachment of feed shaft **20** to mounting clamp **17** using a pin connection (with a quick release snap ring), bolted connection, or other connection. Feed shaft **20** is an elongated linear member having a toothed rack **21**.

Frame **13** includes mounting clamp **17**, feed shaft **20** and moving portion or section **23**. Moving portion **23** includes transverse section **60** and arms **24**, **25** which are spaced apart. Arms **24**, **25** can be generally parallel. An open end **26** is provided to moving portion **23** in between arms **24**, **25** generally opposite drive roller **31**. Moving portion **23** provides sleeve **61** at transverse section **60**. Sleeve **61** is receptive of feed shaft **20** and forms a sliding connection therewith.

A plurality of sheaves or roller guides **27-30** are mounted to moving portion **23**. A tensioner **32** is mounted to moving portion **23** and includes roller guide **74**. An endless diamond

wire **16** is wound about the roller guides/sheaves **27-30**, drive roller **31** and tensioner **32** roller guide **74** as shown. Larger diameter roller **31** is a drive roller **31** drives diamond wire **16** clockwise when viewed in plan (see FIG. **6**), as indicated schematically by arrows **50**. Rollers **27-30** can rotate in the directions illustrated by arrows **59** in FIGS. **6-7** (rotation in the opposite directions is also available). Arrow **57** shows the direction of rotation of drive roller **31**. Arrow **58** in FIG. **6** shows the direction of travel of moving portion **23** in relation to feed shaft **20**. Arrow **56** shows the direction of rotation of roller **74** of tensioner **32**.

Rollers **27-30** can be painted or marked to divide each roller **27-30** into semi-circular areas **51-52** of different color and thus easily show rotational movement during operation, such as when viewed with a remote, underwater camera **81**. Each roller **27-30** is removable from moving section **23** for ease of replacement. Each roller **27-30** rotates upon a vertical shaft **53**, which rotation can be facility by one or more bearings such as two sets of 3 centimeter stainless steel sealed bearings. Each shaft **53** is held in vertical tube **54** with one or more set screws **55**. Set screws **55** enable replacement of a selected roller **27-30** and its shaft **53** as well as vertical adjustment (see arrows **62**, FIG. **8**) by loosening set screws **55**. Set screws **55** can be tightened when a selected roller **27-30** and shaft **53** is located at the proper vertical elevation.

Support vessel **35** at water surface **36** can provide a crane **37** that lifts and lowers cable **15** and any needed rigging (e.g. slings). Hydraulic fluid supply lines **33** are provided for supplying hydraulic fluid from support vessel **35** and hydraulic control unit **34** to hydraulic motor drives **40**, **44**.

The apparatus **10** of the present invention can be remotely operated underwater from a vessel **35**. Support vessel **35** can provide a hydraulic control unit **34** that enables remote operation of cutting apparatus **10**. Arrow **38** in FIG. **3** illustrates the lifting of a section of structure or tubular or target **11** after it has been cut using cutting apparatus **10** at cut **39**.

A pair of motor drives **40-44** are each provided with hydraulic flow lines. These hydraulic flow lines are a part of the hydraulic fluid supply **33**. The motor drive **40** is provided with hydraulic lines **41**, **42**. The motor drive **44** is provided with hydraulic lines **45**, **46**. Motor drive **44** powers drive roller **31**. Motor drive **40** powers pinion gear **49**. The motor drive **40** powers smaller gear **47** which powers larger gear **48** using belt drive **43**. Pinion **49** is attached to larger gear **48** and rotates therewith. The pinion **49** engages toothed rack **21** of feed shaft **20**.

FIGS. **9-11** show the tensioning mechanism **32** in more detail. The tensioning mechanism **32** employs a t-shaped beam that includes web **63** and flange **64**. End plate **65** is attached to web **63** flange **64** as shown in FIG. **11**. A threaded rod **68** is mounted to end plate **65** at opening **67**. Threaded rod **68** also attaches to nut **69** at internally threaded opening **70**. Adjustment head **66** attaches to and rotates with threaded rod **68**. A rotation of rod **68** using adjustment head **66** in the direction of arrows **73** in FIG. **11** effects a sliding movement of bearing/slide **71** as illustrated by arrows **72** and **72'** in FIG. **11**. This adjustment of adjustment head **66** to effect a movement of slide **71** changes the position of tensioner **32** roller **74** as shown in FIG. **9**. By moving the roller **74** in FIG. **9** from the position shown in hard lines to the position shown in phantom lines, tension can be applied to diamond wire **16** as indicated by arrow **77** in FIG. **9**. Roller **74** provides an annular groove **75** that is receptive of diamond wire **16** as shown in FIGS. **10** and **11**. An annular flange or stop **76** can be provided at the end portion of threaded rod **68** opposite adjustment head **66** for limiting the travel of slide/bearing **71** away from end plate **65**. A flange **66'** (e.g., washer) can be welded on rod **68** to limit movement of rod **68** in the direction of arrow **72'**.

FIG. **12** shows camera mount **80** for supporting a video camera **81** and light **92**. The video camera **81** enables an operator at a remote location such as a hydraulic control panel to view cutting operations when conducted underwater. Camera mount **80** includes a post **82** that can be 1-shaped as shown in FIG. **12**. Post **82** can be mounted in tube **83** and secured with set screws **78**. Camera **81** and light **92** can be remotely operated using cable **79** or other known instrumentation and can be adjusted rotationally in the direction of arrow **93** (or the opposite direction of arrow **93**), and also adjusted vertically in the directions of arrows **94** and **95**. Camera **81** can provide a video signal for monitor **117** which is being viewed by operator **116** (FIG. **19**).

FIG. **13** shows an optional cooling system **84**. Cooling system **84** employs a header or flow line **85** fitted with one or more nozzles **86**. Each nozzle **86** is capable of directing a water jet **87** to the area being cut as shown in FIG. **13**. Water supply conduit **88** can be used to transmit water to header or flow line **85**. Water supply conduit **88** attaches to header/flow line **85** at tee fitting **89**. Arrow **90** in FIG. **13** illustrates the inflow of water to the cooling system **84** via water supply conduit **88**, tee fitting **89** and flow line/header **85**. Other cooling fluids beside water can be used such as liquid nitrogen.

FIGS. **15** and **16** show an optional hydraulic clamp, designated by the numeral **100**. Clamp **100** provides a receiver **101** that is receptive of feed shaft **20**. Receiver **101** can provide one or more openings **102** that enable a bolted connection to be made between receiver **101** and feed shaft **20**. Hydraulic clamp **100** provides a body **103** with a hinge **104** that pivotally attaches arm **105** to body **103**. Cylinder **106** can be supported at one end on body **103** with a pinned connection **112**, the other end of cylinder **106** provides a pushrod **107** that connects to pivoting arm **105** at pinned connection **108**. Arrows **109** in FIGS. **15** and **16** illustrate a pivoting movement of arm **105** relative to body **103**.

FIGS. **17** and **18** illustrate floatation material **110** that can be bolted to moving portion **23** using bolted connections **111** for example. The floatation material **110** can be any buoyant material such as styrofoam. Floatation material **110** is preferably comprised of a plurality of floatation modules which are detachably connectable to cutting saw **10** such as through bolted connections **111**. In one embodiment a kit of a plurality of different sizes of floatation modules can be included to adjust the amount of buoyant force on cutting saw **10**.

FIG. **19** illustrates a control panel **113**. Control panel **113** can be located on the deck or cabin of vessel **35**. Control panel **113** provides instruments **114** and control valves **115** that enable an operator **116** to control operation of the cutting apparatus **10**. A monitor **117** communicates with camera **81** for enabling the operator **116** to view cutting operations as well as the overall apparatus **10**.

FIGS. **20** and **21** show diamond wire **16** in more detail. The diamond wire **16** can provide an elongated wire rope body **121** with spaced apart annular abrasive members **122** mounted thereon as shown in FIGS. **20** and **21**. In an alternative embodiment the cutting wire **16** can be a continuous diamond impregnated wire system. Both of these types of cutting wire **16** are conventionally available.

FIGS. **22** and **23** show adjustment of the tensioner mechanism **32** (FIG. **22**) and removal or replacement of a wire **16** and/or of a roller **29**. In FIG. **22**, a diver **118** uses a wrench **119** to adjust adjustment head **66** of tensioner mechanism **32** and adjust the tension on cutting wire **16**. In FIG. **23** diver **118** is shown installing a new wire **16'** to replace original cutting

wire **16** which may have broken during cutting operations (which replacement step is being done completely underwater). In FIG. **23**, diver **118** is shown removing roller guide **29** from tube **54** so that it can be replaced with a spare roller guide **29'** that is shown in FIG. **23** attached to a lift line **120** (which replacement step is being done completely underwater).

Typical Method of Subsea Operation

The following includes steps in one embodiment for operating the cutting saw in a subsea environment:

1. Job to be performed can be discussed at length with customer. Details of the job can include tooling placement on vessel **35**, shipboard power requirements, water depth, casing sizes to be cut, offshore location, departure dock and safety orientation.

2. Cutting saw **10** and support equipment is prepared and function tested prior to transport to job site.

3. Cutting saw **10** and support equipment is transported to job site such as through customer's supply vessel **35** and to the work location that could be a platform, drilling rig, drill ship, work barge, dive boat, or lift boat.

4. Cutting saw **10** and support equipment is offloaded via work platform crane **37** and placed on the deck in accordance with vessel Captain, tool pusher, and/or Customer representative's instructions.

5. Cutting saw **10** hydraulic control **113** is connected to hydraulic power supply unit.

6. Hoses are used to connect control panel **113** and cutting saw **10** via either a single, 4-hose, umbilical hose bundle or two 2-hose umbilical hose bundles. All umbilical hoses are stored on powered reels for ease of transport, unspooling, and reclaiming hoses from the sea floor.

7. 1" hose is connected to the main drive wheel motor **40** of the cutting saw **10** and ½" (or ¾") hose connected to drive motor for cutting saw's axial feed system (rack and pinion system **20**/**21**).

8. Loop of cutting wire **16** is placed around the alignment wheels or sheaves (10" idler pulley wheels **27-30** and the 24" main wire drive wheel **31**). In one embodiment alignment wheels or sheaves **27-30** are painted to be ½ black to allow their rotation to be viewed underwater via a saw mounted camera. When viewing of the rotating wheels substantially appears solid, the wheel speed, and cutting wire **16** speed can be considered adequate for cutting.

9. The tension of the cutting wire loop **16** is applied via the axial tension arm **32** using a wrench (FIG. **9**). This adjustment is easily made in a subsea environment should cutting wire replacement be necessary. The cutting saw **10** need not be brought to the surface for changing the cutting wire or for adjusting wire tension.

10. Operators start the hydraulic power unit, adjust appropriate output pressure and gallons per minute flow rate and test the cutting saw **10** operation while the cutting saw **10** is above water (e.g., on the surface of the deck of the ship **35**).

11. Once test is deemed good, diver support crews attach sonar positioning beacons, observation camera **81** and light, visual illumination/indication (cylalume glow sticks) and any necessary hand tools for wire changes sub-sea.

12. Deck rigging crews connect the furnished three part sling to the big or small block of the vessel crane **37**.

13. Once a diver is in the water and at depth, the vessel crane **37** lowers the cutting saw **10** to the depth and location of the target **11** to be cut. Air bags and/or foam floatation modules **110** can be attached or added to the cutting saw **10** to approximate a neutral buoyancy condition for the cutting saw **10**, and to increase the diver's ability to manipulate the cutting saw **10**.

14. Diver manually manipulates cutting saw **10** to the desired cut area on target to be cut and provides directions (e.g., oral or verbal such as through a transmitter) to the crane operator to assist in vertically positioning the cutting saw **10** as needed.

15. Once the desired cut position is reached, the diver secures (clamp **17**) the cutting saw **10** to the target to be cut (e.g., using manual chain binders or come-along or a hydraulically operated clamp **100** can be used in place of the manual chain binder assembly **17**.

16. Once the cutting saw **10** is mounted, the diver removes all attached slings, tooling and handling ropes. The diver ensures that any umbilical and hydraulic lines are clear of all mechanical moving items to ensure unimpeded operation of the cutting saw **10**.

17. The diver affixes the crane block with slings and shackles to the item **11** being cut to provide safe holding of the work piece **11'** during and after cutting. This step also provides lifting tension on the item to open the cut and aid in the cutting process.

18. The diver returns to a dive bell or to surface prior to initiating saw operation.

19. Once instructed to commence cutting by the Dive Supervisor, the hydraulic power unit is started and adjusted for the appropriate pressure and flow rate.

20. The observation camera **81** and light is turned on to monitor the cut. All cutting is recorded on digital video disk for later assessment.

21. The hydraulic power unit is engaged providing pressure to the system. The operator having verified all parameters starts the cutting machine with the control panel **113**.

22. Once a free-spinning drive motor **40** baseline pressure is reached, the diamond wire saw drive motor **40** pressure is monitored for increased pressure indicating that the diamond wire **16** is cutting.

23. An optimum increased pressure on the cutting wire **16** drive motor **40** is approximately 100-300 psi and may be adjusted by incremental movement of the rack and pinion axial wire feed mechanism **20**/**21**.

24. Pressure is monitored throughout the cut. Increased pressure spikes can indicate movement in the target **11** being cut giving the operator **116** an indication of pinching of the diamond wire **16** or a complete drop in pressure, indicating a broken wire **16** or that the cut is complete. Visual indications are provided through the camera **81** and light monitoring system if water clarity allows.

25. If the cut is not complete, a new diamond cutting wire **16'** is placed on the 10" idler pulleys **27-30** and tensioned manually by the diver **118** with verbal instruction from a Technician via the Dive Supervisor.

26. All hydraulics are disengaged via the control panel **113** once the cut is complete, or in the event that there is a diamond wire **16** breakage.

27. Once the cut is complete, the vessel **37** crane operator moves the extracted cut piece **11'** to the sea floor or returns the piece to the work deck for offloading at a later time.

28. Following a diver survey of the area to ensure no damage to outlying structures or equipment has occurred; the vessel crane **37** block is lowered to the diver and reattached to the diamond wire saw **10** via the supplied three part sling.

29. The diver **118** removes the manual chain clamping system **17** and gives verbal guidance to the crane operator for returning the diamond wire saw **10** to surface.

30. Once the cutting saw **10** is on the vessel **35** work deck, all hydraulic hoses from the hose reel to the saw are disconnected.

31. The cutting saw **10** is thoroughly rinsed with a freshwater solution and all moving components are lubricated.

32. Cutting saw **10** is maintained on standby until further use is needed.

33. All video footage recorded is reviewed for analysis and improvement.

34. A cutting report can be provided to the customer which can include the video footage.

Using Cutting Wire Resistance to Determine Advancement of Cutting Wire

In one embodiment the operator **116** of the saw device can be above water and the cutting saw **10** be below water. In one embodiment the operator can use the resistance on the cutting wire **16** to determine when to advance the cutting wire **16** of the cutting saw **10**. In one embodiment the resistance on the cutting wire **16** can be relatively determined based on the back pressure (e.g., hydraulic back pressure) to the driving motor **40** for the cutting wire **16**. In one embodiment the cutting process includes the step of advancing the cutting wire **16** a short distance, and watching the resistance on the cutting wire **16** increase and then over time decrease (as the cut on the target **11** is made), and after noting the decrease in wire **16** resistance, again advancing the cutting wire **16** and watching the resistance on the cutting **16** wire again increase. In one embodiment these two steps of advancing the cutting wire **16** a short distance, and watching the resistance on the cutting wire **16** first increase and then decrease before again advancing the cutting wire **16** are repeated a plurality of times until the cut is made through the target **11**.

Replacement of Cutting Wire and Alignment Wheels Underwater

In one embodiment the wire **16** can be replaced while the cutting saw **10** is underwater, such as during the middle of a cut and without moving the cutting saw **10** above water (e.g., see FIGS. **22** and **23**).

In one embodiment while underwater after a first cutting wire **16** has broken a second cutting wire **16'** can be placed on the saw device **10** and properly tensioning without having to first return the saw device **10** to the surface (e.g., see FIGS. **22** and **23**). In one embodiment the axial feed wire tensioning system **32** can be used to properly tension the cutting wire **16** while the saw device **10** remains underwater (FIG. **22**).

In one embodiment one or more of the alignment wheels or sheaves **27-30** and **32** can be replaced while the saw device **10** is underwater, such as during the middle of a cut and without moving the saw device **10** above water.

Using Both a Push and a Pull Types of Cuts on a Single Cut

In one embodiment the method includes the step of:

(a) starting a cut with a pushing (or pulling) type cut;

(b) before the cut is completed, stopping the cutting wire **16** and at least partially removing the cutting wire **16** from the alignment wheels or sheaves **27-30**;

(c) moving the saw device **10** into a different pulling (or pushing) type cut position but without bringing the cutting saw **10** above;

(d) placing cutting wire **16** on the alignment wheels or sheaves **27-30**; and

(e) completing the remaining portion of the cut in the other type of cutting mode.

In one embodiment step "c" is completed without repositioning the clamp **17** holding the cutting saw **10** on the target **11**.

In one embodiment step "c" is performed by moving the cutting frame **23** to a substantially extended position. In one embodiment the cutting frame **23** is moved to a completely extended position.

In one embodiment step "c" is performed by moving the cutting frame **23** to a substantially retracted position. In one embodiment the cutting frame **23** is moved to a completely retracted position.

In one embodiment the same cutting wire **16** is used during steps "a" and "e."

In one embodiment a different cutting wire **16'** is in step "e" as that cutting wire **16** used in step "a".

In one embodiment the cutting wire **16** used in step "a" is a loop which is broken into a wire string with two ends and during step "d" the two ends are reconnected to form a loop.

In one embodiment the cutting wire **16** used in step "a" remains in a loop and is placed around the target **11** being cut before step "d" such as by being run down the top 11" of target **11**.

In one embodiment the tensioning mechanism **32** is used to loosen the cutting wire **16** in step "b."

In one embodiment the tensioning mechanism **32** is used to tension the cutting wire **16** in step "d."

In one embodiment the method includes the step of:

(a) starting a cut with a pushing (or pulling) type cut;

(b) before the cut is completed, the first cutting wire **16** breaking;

(c) removing the first cutting wire **16** from the alignment wheels or sheaves **27-30**;

(d) without bringing the cutting saw **10** above water installing a second cutting wire **16'** on the alignment wheels or sheaves **27-30**; and

(e) completing the remaining portion of the cut with the second cutting wire **16'**.

In one embodiment the tensioning mechanism **32** is used to loosen the first cutting wire **16** in step "c."

In one embodiment the tensioning mechanism is used to tension the second cutting wire **16'** in step "d."

In one embodiment the method includes the step of vertically adjusting at least one of the alignment wheels or sheaves (**27-30** and/or **32**) while the cutting saw **10** remains underwater.

The following is a list of Reference numerals which are used in this application.

LIST OF REFERENCE NUMERALS

Reference Number Description

10 cutting apparatus
11 target
12 seabed
13 frame
14 shackle
15 lift cable
16 diamond wire
16A cutting point of diamond wire
17 mounting clamp
18 cable/chain attachment
19 cable/chain attachment
20 feed shaft
21 toothed rack
22 receiver
23 moving portion
24 arm
25 arm
26 open end
27 sheave/roller guide
28 sheave/roller guide
29 sheave/roller guide
30 sheave/roller guide

31 drive roller
32 tensioner mechanism
33 hydraulic fluid supply
34 hydraulic control unit
35 support vessel
36 water surface
37 crane
38 arrow
39 cut
40 motor drive
41 hydraulic line
42 hydraulic line
43 drive belt
44 motor drive
45 hydraulic line
46 hydraulic line
47 smaller gear
48 larger gear
49 pinion
50 arrow
51 section
52 section
53 shaft
54 tube
55 set screw
56 arrow
57 arrow
58 arrow
59 arrow
60 transverse section
61 sleeve
62 arrow
63 web
64 flange
65 end plate
66 adjustment head
67 plate opening
68 threaded rod
69 nut
70 intervally threaded opening
71 bearing/slide
72 arrow
73 curved arrow
74 roller guide
75 annular grove
76 annular flange/stop
77 arrow
78 set screw
79 cable
80 camera mount
81 camera
82 post
83 tube
84 cooling system
85 flow line/header
86 nozzle
87 water jet
88 water supply conduit
89 tee fitting
90 arrow
92 light
93 arrow
94 arrow
95 arrow
100 hydraulic clamp
101 receiver
102 opening
103 body
104 hinge
105 pivoting arm
106 cylinder
107 pushrod
108 pinned connection
109 arrow
110 floatation material
111 bolted connection
112 pinned connection
113 control panel
114 instrument
115 control valve/lever
116 operator
117 monitor
118 diver
119 wrench
120 lift line
121 wire rope body
122 abrasive member

All measurements disclosed herein are at standard temperature and pressure, at sea level on Earth, unless indicated otherwise. All materials used or intended to be used in a human being are biocompatible, unless indicated otherwise.

The foregoing embodiments are presented by way of example only; the scope of the present invention is to be limited only by the following claims.

The invention claimed is:

1. A wire saw apparatus comprising:

a) a frame that includes a clamp configured to attach to a target that is to be cut and a moving portion mounting to the clamp for movement relative to the clamp;

b) an elongated beam mounted to the clamp and extending away from the clamp and target;

c) the moving portion including a pair of spaced apart arms, an open end positioned near the clamp and a transverse bar that connects the spaced apart arms opposite the open end;

d) the moving portion having a powered driver operably connected to the beam which driver effects linear and non-rotational movement of the moving portion of the frame along the beam;

e) a plurality of roller guides on the moving portion of the frame including at least one roller guide mounted at the free end of each arm;

f) a drive roller on the moving portion, the drive roller being rotatable by a powered motor drive; and

g) a diamond wire wound upon the drive roller and guide rollers so that when the drive roller is rotated, the diamond wire travels around the moving portion and from one roller to another roller.

2. The wire saw apparatus of claim **1**, wherein the powered driver travels with the moving portion.

3. The wire saw apparatus of claim **1**, wherein the rollers and diamond wire define a cutting plane and the elongated beam includes a toothed rack located below the cutting plane and a drive motor is operably connected to the toothed rack via a gear.

4. The wire saw apparatus of claim **1**, wherein the arms are spaced apart a distance that defines the maximum thickness of a target that can be cut.

5. The wire saw apparatus of claim **1**, wherein the arm free ends and transverse bar are spaced apart a distance that defines the maximum thickness of a target that can be cut.

6. The wire saw apparatus of claim **1**, further comprising a tensioning mechanism that enables adjustment of the tension of the diamond wire.

7. The wire saw apparatus of claim 1, wherein the diamond wire travels at a speed of between about 20 and 30 feet per second.

8. The wire saw apparatus of claim 1, wherein at least one of the rollers is marked with different patterns so that rotation of the rollers is visible even via underwater camera and remote monitor.

9. The wire saw apparatus of claim 1, wherein the clamp is secured to the target with a hydraulic clamping mechanism.

10. The wire saw apparatus of claim 1, wherein the arm free ends are connected with a section of wire that cuts through the target as the moving portion of the frame travels along the beam and towards the clamp.

11. The wire saw apparatus of claim 1, wherein the guide rollers on the arm free ends are connected with a section of wire that extends across the open end of the moving portion.

12. The wire saw apparatus of claim 1, wherein the moving portion carries a camera and light mount.

13. The wire saw apparatus of claim 1, wherein the guide rollers are removably attached to the moving portion of the frame.

14. A wire saw apparatus comprising:

a) a clamp configured to attach to a target that is to be cut;

b) an elongated beam mounted to the clamp and extending away from the clamp and target;

c) a moving frame mounted on the elongated beam and being movable along the beam, the frame including a pair of spaced apart arms, an open end positioned near the clamp and a transverse bar that connects the arms opposite the open end;

d) a motor operably connected to the beam which motor effects linear and non-rotational movement of the moving frame along the beam;

e) a plurality of roller guides on the moving portion of the frame including at least one roller guide mounted at the free end of each arm;

f) a drive roller on the moving portion, the drive roller being rotatable by a second motor drive;

g) a diamond wire wound upon the drive roller and guide rollers so that when the drive roller is rotated with the second motor drive, the diamond wire travels around the moving portion and from one roller to another roller.

15. The wire saw apparatus of claim 14, wherein the drive roller has a diameter that is more than two times any of the guide rollers.

16. The wire saw apparatus of claim 14, wherein the diamond wire travels at a speed of between about 20 and 30 feet per second.

17. A method of cutting an underwater target, comprising the steps of:

a) lowering a cutting apparatus to a position that is next to an underwater target to be cut, the target having a longitudinal axis;

b) attaching the cutting apparatus to the target with a clamping mechanism;

c) wherein in step "b" the cutting apparatus includes a frame that has a clamp configured to attach to a target that is to be cut and a moving portion mounting to the clamp for movement relative to the clamp, a beam mounted to the clamp and extending away from the clamp and target, the moving portion includes a pair of spaced apart arms with an open end of the arms positioned near the clamp and a transverse section that connects the spaced apart arms opposite of the open end, and wherein a diamond wire is supported for travel upon the frame, the wire connected to a plurality of rollers including at least one powered drive roller that moves the wire;

d) advancing the moving portion toward the target while the diamond wire is traveling upon the rollers; and

e) wherein in step "d" a driver engages the beam, which engagement causes the advancement of the moving portion linearly in a direction generally perpendicular to the longitudinal axis of the target.

18. The method of claim 17, wherein the cutting mechanism is operated remotely from a vessel using a control panel.

19. The method of claim 18, wherein remote operation includes monitoring the cutting with an underwater camera that transmits a signal to a monitor on the vessel.

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